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Concurso de Projetos de I&D em Todos os Domínios Científicos - 2022
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Estado
Submetida

Submetida em
10.03.2022 11h52 GMT

Dados gerais

Investigador responsável
Luís Vilhena

Título do projeto em português
Design Ecológico de compósitos novos e inovadores à base de Carboneto de Tungsténio

Título do projeto em inglês
Eco-Design of new and innovative tungsten carbide-based composites

Acrónimo do projeto
ECO-WC

Palavras-chave em português
Carbonetos de tungsténio, Novos aglutinantes, Resistência ao desgaste, Resistência à corrosão,

Palavras-chave em inglês
Tungsten Carbides, New binders, wear resistance, Corrosion resistance,

Tipologia do projeto
Projetos de Investigação Científica e Desenvolvimento Tecnológico

Área científica principal

Domínio científico
Ciências da Engenharia e Tecnologias

Área científica
Engenharia Mecânica

Subárea científica
Engenharia Mecânica

Painel de avaliação
Mechanical Engineering and Engineering Systems

Fundamentação da seleção da área científica
The proposed research project aims the design of new and innovative cemented carbide products (WC based composites with a metallic phase, called hardmetals) that contribute to the reduction/substitution of critical materials like Co, the binder commonly used in these composites. It is easy to understand that this project could be included also in the scientific area of materials engineering. However, the choose of the mechanical engineering area was done taking into account that most of the tasks associated with the project are included in the area of mechanical characterization and tribological characterization (Tribocorrosion) and that the core CV of most of the researchers team, as well the PI associated with this project is in the mechanical engineer scientific area.

Calendarização

Data de início
01.01.2023

Duração (meses)
36

Instituições

Instituição proponente

Instituição	Unidade de I&D
Universidade de Coimbra	→ Universidade de Coimbra - Faculdade de Ciências e Tecnologia da Universidade de Coimbra - Centro de Engenharia Mecânica, Materiais e Processos (CEMMPRE)

Descrição da instituição e respetivas competências para o desenvolvimento do projeto

The CEMMPRE develops interdisciplinary research in the areas of Mechanical and Materials Engineering and other related areas (last FCT evaluation: excellent). The CEMMPRE has the suitable facilities to provide the applicant with the conditions for performing this work plan. CEMMPRE supports the applicant and will carry out all the efforts for the successful accomplishment of the objectives. The relationships between CEMMPRE and other institutions (national/international, academia/industry), eg. Advanced Production and Intelligent Systems Associated Laboratory and Instituto Pedro Nunes-IPN, have led to stimulating new ideas, which is also an added value for supporting researchers in all processes (from idea to business). The laboratories LED&Mat and LEC (IPN) from CEMMPRE, are an alternative for supporting the candidate.

Instituições participantes

País	Instituição	Unidade de I&D
PORTUGAL	Universidade de Aveiro	→ Universidade de Aveiro - CICECO- Instituto de Materiais de Aveiro

Descrição da instituição e respetivas competências para o desenvolvimento do projeto

The associate laboratory CICECO – Aveiro Institute of Materials, formerly CICECO-Centre for Research in Ceramics and Composite Materials, was created in March 2002 at the University of Aveiro, Portugal, with the mission of developing the scientific and technological knowledge necessary for the innovative production and transformation of ceramics and organic-inorganic hybrids and materials for a sustainable development. CICECO is the largest Portuguese institute in the field of materials science and engineering, with over 470 people comprising 47 academic staff, 122 full-time researchers and, in December 2020, 31 post-doctoral associates, 203 PhD students and 52 other students. Activities are supported by 15 technicians and administrative personnel.

País	Instituição	Unidade de I&D
PORTUGAL	Durit - Metalurgia Portuguesa do Tungsténio, Lda	→ Durit - Metalurgia Portuguesa do Tungsténio, Lda

% de autofinanciamento no orçamento

50

Descrição da instituição e respetivas competências para o desenvolvimento do projeto

Durit Hartmetall have been developing and producing precision tools and engineering components made of tungsten carbide for more than 30 years. Durit is also focused on partnership and actively and curious about new experiences, in order to understand requirements, recognize concepts, and find better solutions. Combining experience, expertise, and an active hands-on mentality.

Instituições de colaboração

Equipa de investigação

Investigador responsável

Luís Vilhena Nuclear IR 40% de dedicação

Ciência ID
301C-53C9-5BEF

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Coimbra

CV
Obtido em 07-03-2022 at 09:09:25 GMT

Sinopse do CV
Having a diversified CV with graduation in Chemical Engineering - specialization in Processes and Industry and PhD in Mechanical Engineering area of Mechanical Design. Having exercised different functions, alternating from Materials Engineering to Surface and Physical Engineering. Considering also a Zig-Zag career path, having served, both in research centres of national and foreign universities as well as in international organizations with a strong industrial component and at interdisciplinary institutes.

In the last five years, the candidate has been involved in different projects related with **Biotribology** and **Tribocorrosion**. The candidate occupies the 24th and 20th researcher position respectively, in the citation number on these keywords in the goggle scholar platform.

Published 26 articles in International journals (*Scopus* - **documents**: 30; **h-index**: 9; **total citations**: 548), 28 works in conference proceedings and he participated in 32 conferences and meetings in foreign countries where he gave 25 presentations. He participated in 6 projects and he was reviewer for 26 international peer-reviewed-journals where he reviewed 56 research works. He was supervisor of 13 master thesis, three of them from the Erasmus Mundus Joint European Master in Tribology of Surfaces and Interfaces. He was member of the jury of 1 PhD thesis, 2 PhD project thesis and 16 master thesis He also gave 8 presentations at national level in dissemination of funding opportunities (FP7 and Horizon 2020).

The author is member of the editorial board of different journals: Smart Science (Taylor & Francis Online), Materials (MDPI) and Lubricants (MDPI)

Custo total (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Membros

Alexandre Ferro Rocha Membro 20% de dedicação

Associação
Confirmada

Ciência ID
5814-1F72-364C

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Aveiro

CV
Obtido em 08-03-2022 at 09:48:32 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Amílcar Lopes Ramalho Nuclear Membro 15% de dedicação

Associação
Confirmada

Ciência ID
BF1E-6E19-2516

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Coimbra

CV
Obtido em 07-03-2022 at 11:47:59 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Ana Maria Oliveira Rocha Senos Nuclear Membro 15% de dedicação

Associação
Confirmada

Ciência ID
5617-7F2C-EC74

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Aveiro

CV
Obtido em 08-03-2022 at 16:42:41 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

António Alexandre da Cunha Bastos Nuclear Membro 15% de dedicação

Associação
Confirmada

Ciência ID
6913-6D0D-E97D

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Aveiro

CV
Obtido em 15-02-2022 at 11:39:02 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Joaquim Sacramento Nuclear Co-investigador responsável 25% de dedicação

Associação
Confirmada

Ciência ID
6B1F-67E2-5680

Instituição à qual está associado no âmbito do projeto de investigação

Durit - Metalurgia Portuguesa do Tungsténio, Lda

CV
Obtido em 10-03-2022 at 09:47:57 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Pedro Pereira Membro 15% de dedicação

Associação
Confirmada

Ciência ID
C715-3298-5486

Instituição à qual está associado no âmbito do projeto de investigação
Universidade de Aveiro

CV
Obtido em 09-03-2022 at 18:36:22 GMT

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	0,00 €	0,00 €	0,00 €	0,00 €

Novas contratações

(BI-a - 04) Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG 100 % de dedicação

Instituição
Universidade de Coimbra

Tarefas
Design experimental setup and characterization of corrosion and tribocorrosion behaviour · 9.6 pessoa * mês
Characterisation of the abrasive wear resistance of different WC-based composites · 9.6 pessoa * mês
Cavitation erosion to evaluate the integrity of WC-based composites · 9.6 pessoa * mês
Final diagrams for WC-based composites · 2.4 pessoa * mês
Literature research · 4.8 pessoa * mês

Custo envolvido (em euros)

2023	2024	2025	2026	Total
15 523,04 €	15 661,77 €	15 801,88 €	0,00 €	46 986,69 €

(BI-a - 06) Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG 100 % de dedicação

Instituição
Universidade de Aveiro

Tarefas
Design of novel WC-based composites · 6.3 pessoa * mês
Liquid phase sintering of novel WC-based composites · 5 pessoa * mês
Structural, microstructural and mechanical characterization · 6.7 pessoa * mês

Custo envolvido (em euros)

2023	2024	2025	2026	Total
0,00 €	18 919,60 €	3 503,92 €	0,00 €	22 423,52 €

Consultores

-

Sinopse do cv da equipa

Alexandre Bastos is a researcher at the Department of Materials and Ceramics Engineering of the University of Aveiro where he is dedicated to the investigation and teaching of metallic corrosion and electrochemical processes, with more than 80 SCI papers published, 3 book chapters and 150 communications in international congresses (as author and co-author). He is also involved in supervising PhD students (2 concluded, 3 ongoing). The role in this project is in the planning, implementation, and analysis of corrosion tests for the specimens under development.

Amílcar Ramalho, is Dean of Mechanical Engineering Department of the University of Coimbra and is the head of the Mechanical and Intelligent Manufacturing Group of the research Centre for Mechanical Engineering, Materials and Processes (CEMMPRE). Amilcar Ramalho is included in the Elsevier database of the top 100,000 by c-score (with and without self-citations) or a percentile rank of 2% or above, according to both career-long and single year impact (2020), in the field of Engineering. He is co-author of around 300 papers in international journals and conferences (H-index 26; >2175 citations). He belongs to the editorial board and collaborates as reviewer of several international journals. His main research areas are: Friction and wear of engineering material, tribological characterization of coated surfaces, Mechanical and tribological behaviour of biomaterials, development of tribological testing equipment. It is undeniable that his inclusion in the present project team represents an added value, especially considering the main objectives that are intended to be achieved.

Ana Senos has been involved in the investigation of ceramics and nanocomposites processing, on the topics of sintering kinetics, microstructural development, grain boundary design, constrained sintering, and the relation with the electrical answer and mechanical behavior of materials. Current interests are focused on development of nanostructured materials for structural, electrical and nuclear applications and on the study of grain boundary phenomena in electronic functional materials (2D, 3D), for microwave and energy applications. Has (is) supervising *18* Master students, *12* PhD students and *5* Post-docs. Is author (co-authored) of *126* publications, including *3* Book Chapters, 101 papers (90 from SCI), *19* proceedings and *2* patents, with ca. *1300* citations (h-index=*22*). She has about *130 communications* as oral and poster presentations or as invited speaker.

Joaquim Sacramento is coordinating professor at the University of Aveiro and is also an assistant to the direction of DURIT and responsible for the area of metallurgy research and development, having supervised several Master's theses in the industrial environment. He is the author of a considerable number of publications in the field of carbides.

Resumo

Resumo em português

O projeto de pesquisa proposto visa o design de novos e inovadores produtos de metal duro (compósitos à base de WC com uma fase metálica, chamados metais duros) que contribuem para a redução / substituição de materiais críticos como o Co, o ligante comumente usado nesses compósitos. Conforme mostrado na tabela abaixo (Tabela 1), o Co faz parte da lista de 2017 de 27 matérias-primas críticas com alto risco de fornecimento e alta importância econômica, às quais o acesso confiável e sem obstáculos é uma preocupação para a indústria e as cadeias de valor europeias. Além disso, a escassez de matérias-primas como o Co resultou em um aumento de preço. Existem também preocupações ambientais e problemas de saúde. O aglutinante padrão mais comum - cobalto - foi recentemente identificado como um risco ambiental e para a saúde [1–3] e está sendo reclassificado como cancerígeno, mutagénico e tóxico para a reprodução. Prevê-se que essa reclassificação tenha ramificações significativas para a indústria de processamento de metais em pó [4]. Embora uma solução seja melhorar os controles de engenharia durante o processo para reduzir a exposição ao pó de Co, aqui nos concentramos em explorar a possibilidade de substituir o ligante de cobalto por alternativas não tóxicas no sistema de WC. Além disso, o presente projeto de pesquisa pode criar valor no sentido de que carbonetos cimentados com ligantes modificados ou alternativos serão desenvolvidos para aumentar a extensão da durabilidade do produto, aumentando a resistência ao desgaste e à corrosão ou facilitando sua reutilização, remanufactura ou reciclagem, que é aproximadamente zero, de acordo com a Tabela 1, apresentada anteriormente (taxa de entrada de reciclagem no final da vida útil igual a zero). Consequentemente, a vida útil das ferramentas e peças com propriedades aprimoradas pode ser aumentada, reduzindo a necessidade de substituir as peças obsoletas. Desta forma, demonstra alto potencial para promover o desenvolvimento sustentável de acordo com a Agenda 2030, principalmente com o Plano de Ação da Economia Circular da UE. As questões geopolíticas envolvidas em sua extração primária também direcionaram a pesquisa para o desenvolvimento de ligantes Co-pobres ou, de preferência, livres de Co, uma vez que, como pode ser visto na Tabela 1, a UE é altamente dependente das importações de metais e produtos minerais (entre 60 e 100 % de todos os metais usados por sua indústria), uma vez que a produção doméstica é limitada a 3% da produção global, enquanto o consumo é de cerca de 20% do total. Particularmente, no caso de Co. A substituição do Co será baseada em modelos matemáticos, onde o design de novos compósitos baseados em WC será drasticamente reduzido. Uma combinação de modelos termodinâmicos e analíticos será usada para desenvolver o projeto rápido de um aglutinante de metal livre de cobalto para compósitos à base de WC. Além disso, a resistência ao desgaste e à corrosão das composições desenvolvidas será usada como peneira final para selecionar novos carbonetos cimentados com maior eficiência e durabilidade. Este projeto também visa contribuir para o conhecimento do desempenho mecânico da superfície de peças de metal duro, considerando uma extensa caracterização com técnicas desenvolvidas, como erosão-cavitação. Essa equipe multidisciplinar de pesquisa já possui "know-how" e "expertise" em todos os assuntos / tarefas e sinergias propostas, esperados da colaboração entre esses dois centros de pesquisa. CEMMPRE, Centro de Materiais e Processos de Engenharia Mecânica, da Universidade de Coimbra e CICECO, Centro de Materiais de Cerâmica e Compósitos da Universidade de Aveiro. Os pesquisadores do CEMMPRE têm uma vasta experiência na caracterização e execução de ensaios tribológicos, enquanto os pesquisadores do CICECO têm a experiência necessária na caracterização por sinterização e microestrutura de compósitos de WC. A compreensão dos fenômenos envolvidos neste trabalho científico contribuirá para o desenvolvimento de diretrizes, bem como a implementação de protocolos para a produção de compósitos de WC. O parceiro industrial, Durit Lda, é de extrema importância, pois possui uma enorme experiência na produção de compósitos à base de WC e participará no desenvolvimento de novas soluções bem como na sua produção em meio industrial.

Resumo em inglês

The proposed research project aims the design of new and innovative cemented carbide products (WC based composites with a metallic phase, called hardmetals) that contribute to the reduction/substitution of critical materials like Co, the binder commonly used in these composites. As shown in table below (Table 1), Co is part of the 2017 list of 27 critical raw materials with a high supply-risk and a high economic importance to which reliable and unhindered access is a concern for European industry and value chains. Besides that, the shortage of raw materials like Co, has resulted in a price increase. There are also environmental concerns and health issues. The most common standard binder – cobalt – has recently been identified as an environmental and health hazard [1–3] and is undergoing reclassification as a carcinogen, mutagen and reproductive toxicant. It is anticipated that this reclassification will have significant ramifications for the metals powder processing industry [4]. While one solution is to improve engineering controls during the process to reduce exposure to Co powder, here we focus on exploring the possibility of replacing the cobalt binder with non-toxic alternatives in the WC system. In addition, the present research project, can create value in the sense that, cemented carbides with modified or alternative binders will be developed increase the extension of the product durability by increasing the wear and corrosion resistance or the facilitation of its re-use, remanufacturing or recycling, that it’s approximately zero according with the Table 1, presented previously (End-of-life recycling input rate equal to zero). Consequently, the lifetime of tools and parts with enhanced properties can be increased, reducing the need to replace the obsolete parts. In this way it demonstrates high potential to promote the sustainable development according to the 2030 Agenda, mainly with the EU Circular Economy Action Plan. Geopolitical issues involved in its primary extraction, have also driven research into developing Co-poor or, preferably, Co-free binders since as can be seen in Table 1, EU is highly dependent on imports of metals and mineral products (between 60 and 100% of all metals used by its industry) since the domestic production is limited to 3 % of global production, while consumption is about 20 % of the total. Particularly, in the case of Co. The Co replacement will be based on mathematical models, where the design of new WC-based composites will be drastically shortened. A combination of thermodynamic and analytical models will be used in order to develop the rapid design of a cobalt free metal binder for WC based composites. Besides, the wear and corrosion resistance of the developed compositions will be used as final screen to select new cemented carbides with improved efficiency and durability. This project also aims to contribute to the pool of knowledge of the surface mechanical performance of cemented carbide parts by considering an extensive characterization with developed techniques, as erosion-cavitation. This multidisciplinary research team already has "know-how" and "expertise" in all the proposed subjects / tasks and synergies are expected from the collaboration between these two research centres. CEMMPRE, Centre for Mechanical Engineering Materials and Processes, from the University of Coimbra and CICECO, Centre for Ceramics and Composites Materials from the University of Aveiro. CEMMPRE researchers have extensive experience in the characterization and execution of tribological trials, while researchers in CICECO have the necessary experience in sintering and microstructural characterization of WC composites. The understanding of phenomena involved in this scientific work will contribute to develop guidelines, as well as the implementation of protocols for the WC-based composites production. The Industrial partner, Durit L.C. it is of utmost importance since has an enormous experience in production of WC- based composites and will participate in the development of new solutions as well as in their production in an industrial environment.

Resumo para publicação

Resumo para publicação em português

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Resumo para publicação em inglês

-

Revisão da literatura

The demand for WC (tungsten carbide)-based composites is growing worldwide [5] namely for oil, gas, and petrochemical industries. WC–Co cemented carbides are extensively used for a variety of machining, cutting, and drilling applications for their excellent wear resistance and high temperature capability [6]. They have excellent prospects for tribological applications, especially under severe contact conditions [6]. The most conventional grades consist of high-volume fraction of the “hard” hexagonal WC phase embedded within a soft and tough binder phase [6]. They are generally obtained by sintering a tungsten carbide and a metal binder (the standard binder being cobalt). The binder percentage and the carbide grain size determine the

mechanical resistance of the end product and consequently the tribological behaviour. However, in order to impart greater wear and corrosion resistance to the product, other binders

may be used. Fig. 1 shows a schematic picture illustrating the historical development of the cemented carbide industry with the first sintered tungsten carbide produced in 1914 [7]. The invention of the first hard metal tool happened in the year of 1923 and the patent was sold to Krupp in Germany that create a trademark with the name «WIDIA-N» that was created from the German words “Wie” and “Diamond”, meaning “like diamond” (WC–6% Co). The importance of the invention is confirmed by noting that today, ninety years later, the same compositions, made by essentially the same process, are still a very significant product of tool materials industry. The wear resistance of WC–Co was studied by several authors which have identified the extrusion of the binder phase and the fracture and fragmentation of WC grains as the major wear mechanisms [8,9], and in rock drill condition also a contribution of thermal fatigue of the binder [10]. More recently, Beste et al. [11–13] in the Angstrom Laboratory in Uppsala have identified a more local damage mechanism resulting from the impact-induced penetration of small rock fragments into the cobalt binder followed by the fracture and removal of the WC grains. Therefore, concerning the wear resistance of tungsten based cemented carbides, the binder seems to be the weakest link of the microstructure. As an alternative to Co binder, in previous research work conducted by our team [14,15], composites of tungsten carbide and stainless steel (AISI304) binder, containing Fe, Cr and Ni as main elements have been developed using powder metallurgy routes. They were characterized in terms of its phase composition, microstructure and mechanical properties, namely hardness, fracture toughness, Young's modulus and transverse rupture strength. The results reveal that the mechanical properties of the WC–SS composites showed a very good compromise between toughness and hardness and the transverse rupture strength can be improved by using a slight carbon excess. Moreover, corrosion tests carried out on the same materials also revealed a high corrosion resistance of the WC–SS and WC-SS-C composites in chloride containing environment [16]. Nevertheless, the demand for new binders that ensures an increase in resistance to wear and corrosion mainly for the mining industry where tremendously corrosive environments are common, is needed. Nickel aluminides (Ni3Al and NiAl) and iron aluminides (Fe3Al and FeAl) are also being considered as binder materials for WC composites in high-temperature applications and extremely corrosive environments [17,18]. In addition to the property demands of the cermet part, the selection criteria for a suitable binder (either pure metal or alloy) must meet several practical industrial criteria for processing parts, which are currently defined as: (1) reasonably low melting (and therefore processing) temperature, (2) good wettability of the liquid metal binder on the ceramic particles, and (3) a compositional range (e.g. carbon range) within which the liquid solidifies to solid phase without precipitating additional phases [19]. The thermodynamic calculations to predict the available carbon range can also describe the solubility of W and C in the liquid binder and the precipitation reactions which may occur. According to Heather et al. [19] a screening process using mathematical models was developed for the design of novel binder alloys in liquid phase sintered cermets using a combination of thermodynamic and analytical models for composition dependence; heretofore unexamined criteria include capillary flow, viscosity, and surface tension, as summarized in Fig. 2 for Cu binder (at. %) [19]. Fig. 2 shows different physical phenomena as a function of alloying content for Cu binder (at. %) [19]. These new criteria developed by Heather et al. [19] in order to design a liquid metal alloy for cermet systems requires taking into account a series of complex physical phenomena including surface tensions, cohesion energy, viscosity, heats of formation, and the dependency of these parameters on composition and temperature. While the current/traditional binder(s) are mono-elemental, it is likely that next generation binders will need to be multi-component systems. Alloy chemistry is known to dramatically alter aspects of the required figures of merit, and the alloy identification process is compounded by the sheer number of potential interactions in binary, tertiary and higher order systems comprising modern-day alloys.

Plano de investigação e métodos

The search for alternative new binders to the traditional cobalt in tungsten carbide (WC) based composites will be investigated. According to previous studies, elements belonging to the first transition metals series, are some of the solutions envisaged to replace cobalt in WC based composites [20–24]. In the present research work, the effect of different binder materials and binder amounts on the phase composition, microstructure and mechanical properties, namely hardness and fracture toughness, will be investigated. Flat samples of conventional WC–Co, and newly developed WC composites with different binder compositions/amounts will be prepared. The tribocorrosion behaviour (resistance of the combined wear and corrosion) of the different produced cemented carbides will be studied. Comparative experiments will be performed using different tribometers. Worn surfaces will be characterized by optical microscopy, surface scanning topography and scanning electron microscopy. The mechanisms of wear degradation will be discussed. The wear resistance and friction behaviour for the different composites will be analysed and the mechanical properties as hardness and fracture toughness will be correlated with the microstructure and with the tribological behaviour. Innovative aspects consist of the partial/total substitution of cobalt by other binder materials. This multidisciplinary research team already has know-how and expertise in all subjects/tasks proposed and synergies are expected to be developed from the collaboration between these two research centers: the Centre for Mechanical Engineering, Materials and Processes (CEMUC), University of Coimbra and the Department of Materials and Ceramic Engineering (CICECO), University of Aveiro. CEMUC researchers, have high experience in the characterization and execution of tribological tests, while researchers from CICECO have the necessary expertise in sintering cemented carbides at laboratory scale. Related with the Industrial partners, Durit Hartmetall have been developing and producing precision tools and engineering components made of tungsten carbide for more than 30 years. Durit is also focused on partnership and actively and curious about new experiences, in order to understand requirements, recognize concepts, and find better solutions. Combining experience, expertise, and an active hands-on mentality, we pursue the goal to create sustainable relationship. The scientific work will be divided into different Tasks. Each Task will include the corresponding sub-tasks that will cover the essential tools and needs of the specific research topic of the different objectives, as follows:

Task 1 - Literature research.

Task 2 - Design of novel WC-based composites (screening process): Based on mathematical models, the design of new WC-based composites will be drastically shortened by minimizing the experimental matrix. A combination of thermodynamic and analytical models will be used to develop the rapid design of a cobalt free metal binder for WC based composites. The parameters to be investigated comprise chemistry effects on capillary flow, viscosity, surface tension, melting point and then the traditional thermodynamic modelling. The results will be aggregated in a series of easy to interpret diagrams that enable quick identification of systems of interest for further study.

Task 3 - Liquid phase sintering of novel WC-based composites: Liquid phase sintering (LPS) is applied to alloys and composites that melt over a range of temperatures. In the typical situation, the solid grains are soluble in liquid. This solubility causes the liquid to wet the solid, providing a capillary force that pulls the grains together. At the same time, the high temperature softens the solid, further assisting densification. High – diffusion rates are associated with liquids, giving fast sintering or lower sintering temperatures.

Task 4 - Structural, microstructural and mechanical characterization: Different types of WC-based composites will be produced in the scope of the present scientific research work in order to set-up a matrix of experiments for tribocorrosion evaluation. The sintered specimens will be characterized in terms of their phase composition, detailed microstructural features, and mechanical properties.

Task 5 - Design experimental setup and characterization of the corrosion and tribocorrosion behaviour: One of the main objectives of the present research WP is to investigate the wear resistance and corrosion resistance (triboelectrochemical behaviour) of different WC-based composites under different contact conditions. A laboratory specific experimental setup for tribocorrosion experiments will be design and developed with consequently characterisation of the tribocorrosion behaviour for different contact conditions. Comparative experiments will be performed sliding against a ZrO2, Al2O3 or SiC counterbody.

Task 6 - Characterisation of the abrasive wear resistance of different WC-based composites: One of the main objectives of the present research WP is to investigate the abrasive wear resistance of different WC-based composites by ball-cratering method.

Task 7 - Cavitation erosion to evaluate the integrity of WC-based composites: Cavitation erosion is the process of surface deterioration and surface material loss due to the generation of vapour or gas pockets inside the flow of liquid. These pockets are formed due to low pressure well below the saturation vapour pressure of the liquid and erosion caused by the bombardment of vapour bubbles on the surface. The aim of the present WP is to study the structural integrity and erosion resistance of different composites obtained by sintering using an ultrasonic dismembrator equipment.

Task 8 - Final diagrams for WC-based composites.

Referências bibliográficas

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Publicações anteriores

L.M. Vilhena, B. Domingues, C.M. Fernandes, A. M. R. Senos, A. Ramalho, Mechanical and Tribological Characterization of WC-Co and WC-AISI 304 Composites by a newly developed equipment, Materials, 2022, 15(3), 1187
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P. Pereira, L.M. Vilhena, J. Sacramento, A. M. R. Senos, L.F. Malheiro, A. Ramalho, Abrasive wear resistance of WC-based composites, produced with Co or Ni-rich binders, Wear, Volumes 482–483, 15 October 2021
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https://doi.org/10.1016/j.msea.2014.09.064

Tarefas

1 Literature research — 6 meses — De 01.01.2023 a 30.06.2023

Membros

Pessoas / Mês	Alocados
1	Joaquim Sacramento Durit - Metalurgia Portuguesa do Tungsténio, Lda
0.7	Alexandre Ferro Rocha Universidade de Aveiro
0.6	Ana Maria Oliveira Rocha Senos Universidade de Aveiro
0.7	Amílcar Lopes Ramalho Universidade de Coimbra
4.8	BI-a - 04 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Coimbra
1.9	Luís Vilhena Universidade de Coimbra

Descrição

First, the basic knowledge including literature research in the fields of WC-based composites will be obtained.

2 Design of novel WC-based composites — 15 meses — De 01.04.2023 a 30.06.2024

Membros

Pessoas / Mês	Alocados

Pessoas / Mês	Alocados
2.6	Joaquim Sacramento Durit - Metalurgia Portuguesa do Tungsténio, Lda
1.7	Alexandre Ferro Rocha Universidade de Aveiro
1.6	Ana Maria Oliveira Rocha Senos Universidade de Aveiro
6.3	BI-a - 06 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Aveiro

Descrição

Task 2.1. Thermodynamic calculations of the WC/binder interactions: Thermodynamic calculations such as solubility and carbon range will be investigated and binary phase diagrams that represents the region in which liquid binder and WC solidify into solid solution binder and WC, surrounded by deleterious phases, such as the M6C carbide or graphite will be performed. The calculation of such diagrams is part of the secondary screening approach that considers the liquid binder interaction with W and C, while the primary screening focuses on the selection of the binder alloy. The combined criteria provide a systematic approach by which the complex binder alloy problem can be reduced to a series of visual colour coded maps which take into consideration tertiary alloy effects on wetting, melting, viscosity and capillary filling.

Task 2.2. Study the wetting behaviour of the liquid binder on the hardmetal: The main purpose of this task is the determination of the wetting behavior between the cermet and the different contacting binder materials, utilizing the results of the contact angle measurements at high temperatures. The angle between the solid surface and the tangent to the drop surface in the line of three-phase contact line, solid/liquid/gas, will be measured using a VMS-004D - 400x USB Microscope.

Task 2.3. Analysis of the melting/processing temperature: The main purpose of this task is the estimation of melting temperature as a function of composition. These requires free energy equations for the possible phases in the system which is mostly readily available through CALPHAD (Computer Coupling of Phase Diagrams and Thermochemistry) -style modelling. The Thermo-Calc TC-Toolbox for Matlab will be used to rapidly iterate through binder compositions and systems and calculate the melting temperature variations.

Task 2.4. Calculate the viscosity and capillarity of the binder: The main purpose of this task is the determination of the viscosity and capillarity of the binder since the uniform infiltration of these capillary spaces by the liquid metal binder in order to properly bind them is essential for a fully dense part and may be straightforwardly described by the viscosity and capillarity of the liquid binder system. Viscosity changes as a function of alloying and is calculated using the Kozlov-Romanov-Petrov equation chosen from a comparison of several alloy models. Related with capillarity, if we consider the liquid binder movement through/between WC particles as a capillary system, the infiltration metric, $\gamma\cos\theta/2\eta$ can provide a brief description of this flow, where γ is the surface tension, θ the contact angle and η the viscosity.

Task 2.5. Diagram's compilation: A series of easy to interpret atlases will be elaborated that enable quick identification of systems of interest.

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3 Liquid phase sintering of novel WC-based composites 12 meses De 01.10.2023 a 30.09.2024

Membros

Pessoas / Mês	Alocados
2.1	Joaquim Sacramento Durit - Metalurgia Portuguesa do Tungsténio, Lda
1.4	Alexandre Ferro Rocha Universidade de Aveiro
1.2	Ana Maria Oliveira Rocha Senos Universidade de Aveiro
5	BI-a - 06 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Aveiro
5.4	Pedro Pereira Universidade de Aveiro

Descrição

Task 3.1. Blend of the powders in a planetary ball mill: WC and different binder powders will be homogenized with 1.5 wt. % paraffin wax in a planetary ball mill for 20 h at 150 rpm using 2-propanol as milling media.

Task 3.2. Pressing: After drying and sieving (63 µm sieve) the mixed powders will be uniaxial pressed at 190 MPa.

Task 3.3. Sintering studies and Sinter-HIP at industrial furnace: The sintering of WC-based composites will be studied using thermal analyses, DTA/TG and vacuum dilatometry in a graphite dilatometer to define the processing parameters leading to sintered samples up to ~100% of relative density. Sintering of larger samples for wear and corrosion characterization will be produced in a Sinter-HIP industrial equipment at Durit Hartmetall, since it provides large hot zone, high heating speed, good temperature uniformity and fast cooling system.

4 Structural, microstructural and mechanical characterization 16 meses De 01.01.2024 a 30.04.2025

Membros

Pessoas / Mês	Alocados
2.8	Joaquim Sacramento Durit - Metalurgia Portuguesa do Tungsténio, Lda
1.8	Alexandre Ferro Rocha Universidade de Aveiro
1.7	Ana Maria Oliveira Rocha Senos Universidade de Aveiro
6.7	BI-a - 06 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Aveiro

Descrição

Task 4.1. Porosity: The main purpose of this task is the estimation of relative density and the amount of porosity, accordingly with the British Standard ISO 4505:1978.
Task 4.2. Structural/ Microstructural characterization of the sintered samples: Optical images of polished sintered samples will be obtained using optical microscopy (Nikon Microphot). Detailed microstructural characterization and phase identification will be carried out in the sintered samples using scanning electron microscope with energy dispersive spectroscopy (SEM/EDS, Hitachi SU-70, detector Bruker, Quantax 400). X-ray diffraction (XRD, Rigaku) will be performed for qualitative and quantitative structural characterization measurements derived from the Rietveld analyses of XRD spectra. 2D roughness parameters (Ra and Rz) will be calculated according to ISO 4287.
Task 4.3. Determination of Hardness and Fracture toughness: Fracture toughness measurements will be performed with an automatic hardness tester (Zwick/Roell ZHU). An indenter load of 294 N (HV30) will be used for indentation with a dwell time of 15 s. The results presented in this work are the average values of at least 10 individual indentations. The length of radial cracks emanating from the indentation corners will be measured to determine the fracture toughness by the Palmqvist method, a parameter indicative of the
resistance to crack propagation.

5 Design experimental setup and characterization of corrosion and tribocorrosion behaviour 12 meses De 01.07.2024 a 30.06.2025

Membros

Pessoas / Mês	Alocados
1.4	Alexandre Ferro Rocha Universidade de Aveiro
5.4	António Alexandre da Cunha Bastos Universidade de Aveiro
1.4	Amílcar Lopes Ramalho Universidade de Coimbra
9.6	BI-a - 04 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Coimbra
3.8	Luís Vilhena Universidade de Coimbra

Descrição

Task 5.1. Design and develop a laboratory specific experimental setup for tribocorrosion experiments: An experimental setup for tribocorrosion measurements will be specially design

and develop at CEMMPRE and consists of a reaction vessel where three electrodes will be positioned. On modulo will be adapted to allow friction and wear measurements. In this equipment, the normal force is directly applied on the upper specimen holder by a spindle-spring system and is measured by a load cell. The lower specimen holder is supported by a piezoelectric tangential load cell, forming a bridge between the sample holder and the reference base of the equipment, allowing calculation of the friction force.

Task 5.2. Corrosion studies: In this task, the corrosion resistance of the new composites will be analysed in media simulating service environments (aqueous NaCl solution either neutral or acidic). The analysis will be performed by electrochemical techniques such as open circuit potential monitoring, polarization curves (potential-current) and electrochemical impedance spectroscopy (EIS) which will provide the corrosion rates and information about the corrosion mechanisms. The electrochemical assessment will be supported by visual inspection and the surfaces will be analysed in detail using optical and scanning electron microscopy.

Task 5.3. Tribocorrosion experiments: A SP-50 Potentiostat/Galvanostat from BioLogic Science Instruments will be used for electrochemical measurements with a three-electrode assembly consisting of a working electrode (WE), a reference electrode (RE) and a counter electrode (CE). The different specimens to be tested will be sealed to a wall of the triboelectrochemical apparatus with an O-ring and the other side of the specimen will be exposed to the contact with the electrolyte solution with a known contact area. Platinum wire

as counter electrode, and a Saturated Calomel Electrode (SCE) as the reference electrode (E^o = +0.241 V vs SHE) will be used. The EC-Lab® software will be used to control the potentiostat. Open Circuit Potential (OCP) technique will be used to monitor the corrosion potential of the working electrode. At the same time, the different specimens will be also investigated in a reciprocating sliding wear tester. In this test, the upper sample, which is a ball composed of different materials (ZrO2, Al2O3 or SiC) with a diameter of 10 mm, will sliding under oscillating motion against the lower and stationary specimen. The sliding tests will be conducted with a normal load of 17, 23 and 30 N. Thus, using frequency of 1 and 10 Hz and linear peak-to-peak displacement amplitude of 2 mm we will obtained, respectively, 0.004 and 0.04 m/s of average linear velocity. The corrosion resistance will be also evaluated by potentiodynamic polarization method, where the voltage will be scanned from −2000 mV (vs. SCE) to +2000 mV (vs. SCE) at a scan rate of 1 mV/s. To determine the corrosion potential (Ecorr) and corrosion current (Icorr), Tafel plots, representing the current density (A/cm2) vs. potential (V vs. SCE) will be obtained.

Task 5.4. Wear volume calculation: The specific wear rate (k) with units (mm3/Nm) will be calculated using the Archard equation (V=kSN) where V is the wear volume (mm3), S the sliding distance (m), and N the applied normal load of the contact (N). The worn volume of the WC discs will be calculated by integration of the cross-sectional worn area. The volume loss of the spherical ball will be calculated through the evaluation of the volume for the spherical cap. Profilometric measurements will be performed using a Mitutoyo Surftest Sj-500 apparatus from Mitutoyo Corporation.

Task 5.5. Wear mechanism analysis: The surface topography and the wear mechanisms of each specimen will be analysed by observe the worn surfaces using a scanning electron microscopy (SEM, Philips XL-30) and an optical microscopy (OM, Leica DM 4000M LED).

6 Characterisation of the abrasive wear resistance of different WC-based composites 12 meses De 01.07.2024 a 30.06.2025

Membros

Pessoas / Mês	Alocados
1.4	Amílcar Lopes Ramalho Universidade de Coimbra
9.6	BI-a - 04 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Coimbra
3.8	Luís Vilhena Universidade de Coimbra

Descrição

Task 6.1. Tribological experiments: Silicon carbide (SiC) abrasive particles will be used to produce the abrasive slurry. Abrasive slurry concentration with 20% (v/v) will be stirred continuously and feed at the interface between the ball and the specimens at the rate of approximately 2.5 ± 0.5 cm3 min-1. A 0.2 N normal load will be applied by adding dead weights to a hanger arm. Furthermore, the different specimens will be subjected to abrasion with five different sliding distances: 8, 16, 24, 32 and 40 m, respectively: 100, 200, 300, 400 and 500 revolutions of the ball. To minimize the scattering of the results, the ball surface will be prepared by a run-in procedure prior to the starting of the study.

Task 6.2. Wear volume calculation: After tests, the worn surfaces will be characterized by optical microscopy (OM, Leica DM 4000M LED), scanning electron microscopy (SEM, Hitachi SU-70) and by profilometry to determine the wear volume and the dominating wear mechanisms. Profilometric measurements will be performed using a Mitutoyo Surftest Sj-500 apparatus from Mitutoyo Corporation. These measurements are in accordance with DIN/ISO standards. 2D roughness parameters (Ra) were calculated according to ISO 4287.

7 Cavitation erosion to evaluate the integrity of WC-based composites 12 meses De 01.01.2025 a 31.12.2025

Membros

Pessoas / Mês	Alocados
1.4	Amílcar Lopes Ramalho Universidade de Coimbra
9.6	BI-a - 04 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Coimbra
3.8	Luís Vilhena Universidade de Coimbra

Descrição

Task 7.1. Design and develop a laboratory specific experimental setup for Cavitation Erosion: An experimental setup for Cavitation Erosion measurements will be specially design and develop at CEMMPRE and consists of an ultrasonic transducer and a tank filled with a given solution. Cavitation created by the small size probe generated a gradual damage that will be useful for studying the mechanisms of cavitation erosion,

Task 7.2. Cavitation erosion tests: The structural integrity and erosion resistance of different WC-based composites will be analysed using a power supply that converts AC line voltage to 20 kHz electrical energy. This high-frequency electrical energy is fed to a converter where it is converted to mechanical vibrations. The heart of the converter is a lead zirconate titanate electrostrictive element which, when subjected to an alternating voltage, expands and contracts. The converter vibrates in a longitudinal direction and transmits the motion to the horn tip immersed in the solution, which causes cavitation.

8 Final diagrams for WC-based composites	3 meses	De 01.10.2024 a 31.12.2024

Membros

Pessoas / Mês	Alocados
0.5	Joaquim Sacramento Durit - Metalurgia Portuguesa do Tungsténio, Lda
0.3	Alexandre Ferro Rocha Universidade de Aveiro
0.3	Ana Maria Oliveira Rocha Senos Universidade de Aveiro
0.4	Amílcar Lopes Ramalho Universidade de Coimbra
2.4	BI-a - 04 Bolsa de Investigação - Estud. dout. ou lic. e mestres em CNCG Universidade de Coimbra
1	Luís Vilhena Universidade de Coimbra

Descrição

Based on the Mechanical characterization, Tribocorrosion and Cavitation Erosion tests of the newly developed WC-based composites, a series of easy to interpret diagrams that enable quick identification of systems of interest with the mechanical properties wear, corrosion and erosion resistance are going to be assembled.

Calendarização e gestão do projeto

Lista de milestones

Data	Designação	Descrição
01.07.2023	Milestone 1	Insights in the fundamental of WC-based composites
01.07.2024	Milestone 2	Database of results that allow the elaboration of diagrams in order to quickly identified the systems of interest
01.10.2024	Milestone 3	Produced specimens for Tribological, Electrochemical and Cavitation-Erosion characterization
01.05.2025	Milestone 4	Microstructure and Mechanical charcaterization
01.07.2025	Milestone 5	Resistance to Wear and Corrosion estimation

Cronograma

timeline ECO-WC.pdf

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Descrição da estrutura de gestão

The Project will be managed by CEMMPRE - Centre for Mechanical Engineering Materials and Processes, University of Coimbra by the principal researcher. The principal researcher has already experience in management of science and technology projects since he worked during 2 years at the Institute for Interdisciplinary Research and Division of Research Support and Promotion, University of Coimbra. His main activity was project management, setting up of national and international collaborations, Managing relations and partnerships with non-profit as well as corporate entities, Budgeting, forecasting, statistics, and Funding (FP7 and Horizon 2020). The principal researcher has also Project Management skills (Prince2 Foundation certificate and Practitioner certificate).

The research team will oversee carrying out the work proposed and promoting the discussion and exchange of information and ideas between the partners. The report structure will consider one person in charge for each different partner that will be responsible for collect all the information and share it. The communication includes the prompt circulation of information concerning the project, and the exchange of information about the activities in the tasks. For that, working presential meetings, starting with the Kick-off meeting 15 days after the beginning of the project (15/01/2022), will be carried out every three months with the partners and research team to ensure the progress of the scientific work and the achievement of the milestones planned. In addition, there is an informal structure of relations between the people in charge of the three different partners that promises to contribute to an acceleration in decision-making and to

complement the formal structure. In fact, there is already a collaboration between these persons in charge of these three partners, that has already proven to work well, and the characterization of some samples produced by Durit at both, the UA (Microstructure/X-ray diffraction) and at UC (tribological), has already happened in the recent past.

In case the working meetings cannot take place in person, there is a contingency plan that will choose to hold them remotely.

The progress reports will be in a yearly-basis and will gather the following information: global project status evaluation, project successes, problems and constraints, unexpected results, publications, future issues, and overall assessment of progress. A SWOT analysis will be carried out to identify areas of the project that may be optimized.

Questões éticas

Existem questões éticas identificadas neste projeto?

Não

Declarações de ética que considera apropriadas

-

Fundamentação

-

Agenda 2030

Enquadramento da candidatura nos OSD da Agenda 2030

ODS 9: Indústria, Inovação e Infraestruturas | ODS 3: Saúde de Qualidade | ODS 15: Proteger a Vida Terrestre

Fundamentação

Co is part of the 2017 list of 27 critical raw materials with a high supply-risk and a high economic importance to which reliable and unhindered access is a concern for European industry and value chains. Besides that, the shortage of raw materials like Co, has resulted in a price increase. This should be a concern and the sustainable use of the terrestrial ecosystem is one of the goals – objective nº 15 of the United Nations 2030 agenda. There are also environmental concerns and health issues. The most common standard binder – cobalt – has recently been identified as an environmental and health hazard [1–3] and is undergoing reclassification as a carcinogen, mutagen and reproductive toxicant. This part of the objective nº 3 – Ensure healthy lives and promote well-being for all at all ages. Finally it is anticipated that this reclassification will have significant ramifications for the metals powder processing industry. While one solution is to improve engineering controls during the process to reduce exposure to Co powder, here we focus on exploring the possibility of replacing the cobalt binder with non-toxic alternatives in the WC system. In addition, the present research project, can create value in the sense that, cemented carbides with modified or alternative binders will be developed increase the extension of the product durability by increasing the wear and corrosion resistance or the facilitation of its re-use, remanufacturing or recycling, that it's approximately zero according with the Table 1, presented previously (End-of-life recycling input rate equal to zero). Consequently, the lifetime of tools and parts with enhanced properties can be increased, reducing the need to replace the obsolete parts. In this way it demonstrates high potential to promote the sustainable development according to the 2030 Agenda objective nº 9, mainly with the EU Circular Economy Action Plan.

Outros projetos financiados

-

Ficheiros anexos

Fig. 1.jpg

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Fig. 2.jpg

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table 1.pdf

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Indicadores

Indicadores de realização previstos

Descrição	2023	2024	2025	2026	Total
A · Publicações	0	0	0	0	
Livros	0	0	0	0	**0**
Capítulos de livros	0	0	0	0	**0**
Artigos em revistas internacionais	1	3	3	0	**7**
Artigos em revistas nacionais	0	0	0	0	**0**
B · Comunicações	0	0	0	0	
Comunicações em encontros nacionais	1	1	0	0	**2**
Comunicações em encontros científicos internacionais	2	3	3	0	**8**
C · Relatórios	1	1	1	0	**3**
D · Organização de seminários e conferências	0	2	0	0	**2**
E · Formação avançada	0	0	0	0	
Teses de Doutoramento	0	0	0	2	**2**
Teses de mestrado	1	2	1	0	**4**
Outras	0	0	0	0	**0**
F · Modelos	0	0	0	0	**0**
G · Aplicações computacionais	0	0	0	0	**0**
H · Instalações piloto	0	0	0	0	**0**
I · Protótipos laboratoriais	0	0	0	0	**0**
J · Patentes	0	0	0	0	**0**
K · Outros	0	0	0	0	
	0	0	0	0	**0**
	0	0	0	0	**0**
	0	0	0	0	**0**

Divulgação

Ações de divulgação da atividade científica previstas no projeto

The consortium thus established, intends to carry out a policy of promotion and diffusion of scientific activities carried out within the scope of this project through the following forms:

- Disclosure through the appropriate means of the results of its scientific and technological activity not covered by confidentiality reserve.
- Carrying out actions for the dissemination of scientific results, namely among students from the university institutions involved, providing them with direct contact with the ongoing research project and with the partners involved (organization of workshops in the industrial partner dedicated to the finalist students, 4 seminars for the presentation of master's theses and 2 PhD theses related to the project).
- Keeping public information permanently updated, namely on the website of the respective consortium, containing a detailed presentation of the participating institutions and the ongoing research project.
- Publishing 4 scientific papers in open access scientific journals and 3 more papers in journals without open access.
- Participation in 2 national congresses and 8 international congresses.

Orçamento

Instituição proponente

Universidade de Coimbra

Rubrica	2023	2024	2025	2026	Total
Recursos Humanos	15 523,04 €	15 661,77 €	15 801,88 €	0,00 €	**46 986,69 €**
Missões	650,60 €	800,80 €	800,80 €	0,00 €	**2 252,20 €**
Justificação do financiamento solicitado Meetings and other travel costs for scholarships holders for specific work in partner institutions.					
Instrumentos e equipamento científico e técnico	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Subcontratos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Registo de patentes	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstração, Promoção e Divulgação	5 525,87 €	9 001,14 €	5 850,54 €	0,00 €	**20 377,55 €**
Justificação do financiamento solicitado During three years project, participation in 2 National conferences, 3 European Conferences (eg: Ecotrib, Nordtrib, Ibertrib, EuroPM and Leeds-Lyon Symposium) and 2 International conferences (eg: world Tribology Congress, Wear of Materials (WOM) and STLE). Firts year (5525,87 €), Second year (9001,14 €) and Third year (5850,54 €), including transport, inscription, hotel and allowances.					
Adaptação de edíficios e instalações	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Aquisição de bens e serviços	8 750,00 €	3 920,00 €	1 500,00 €	0,00 €	**14 170,00 €**
Justificação do financiamento solicitado 4500€ - (1500 €/year) - Consumables: tungsten filaments for SEM, alcohol, acetone, liquid Nitrogen for EDS, diamond suspension 3 microns, SiC abrasive papers. 750 € - Cost to adapt and design a thermal bath equipment. 2000 € - (2 X 1000 €) For tribocorrosion experiments, two electrodes: (1) Saturated Calomel Electrode (SCE) and (2) Platinum reference electrode 2000 € - Cost to adapt a ultrasonic equipment for cavitation erosion tests in order to measure erosion resistance of materials: (height adjustable test cell, temperature controller, circular container with cooling system and sound proof enclosure) 2500 € - Design and develop a laboratory specific experimental setup for tribocorrosion experiments: reaction vessel, electrodes support, spindle-spring system to applied load, load cells. (2 X 1210 €) Mark Gee is internationally recognized by his work on WC-based composites. His participation will involve two meetings, the first one, in the beginning of 2022 to discuss the preliminary results and the strategies for the tasks 2, 3 and 4. The second meeting will occur in the end of the second year with the objective to discuss the results obtained in the Wear assessment and also the evolution of the Tribocorrosion and Erosion-cavitation tests. A workshop about Wear resistance of WC will be organized synchronized with the second meeting. (https://orcid.org/0000-0002-9858-6390)					
Gastos gerais	7 612,38 €	7 345,93 €	5 988,30 €	0,00 €	**20 946,61 €**
Total	**38 061,89 €**	**36 729,64 €**	**29 941,52 €**	**0,00 €**	**104 733,05 €**

Instituições participantes

Universidade de Aveiro

Rubrica	2023	2024	2025	2026	Total

Rubrica	2023	2024	2025	2026	Total
Recursos Humanos	0,00 €	18 919,60 €	3 503,92 €	0,00 €	**22 423,52 €**
Missões	100,00 €	300,00 €	200,00 €	0,00 €	**600,00 €**

Justificação do financiamento solicitado

Workshops associated with the thematic of the project

Instrumentos e equipamento científico e técnico	6 504,07 €	0,00 €	0,00 €	0,00 €	**6 504,07 €**

Justificação do financiamento solicitado

License for Thermo-Calc software with cemented carbide and metal alloy databases for thermodynamic calculations.

Subcontratos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Registo de patentes	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstração, Promoção e Divulgação	2 500,00 €	3 000,00 €	5 000,00 €	0,00 €	**10 500,00 €**

Justificação do financiamento solicitado

Participation in 3-4 national and international congresses of the specialty, such as EuroPM, Plansee, EuroCorr, SPM and 1-2 publications in “Open Access”

Adaptação de edíficios e instalações	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Aquisição de bens e serviços	6 000,00 €	6 000,00 €	3 000,00 €	0,00 €	**15 000,00 €**

Justificação do financiamento solicitado

Reagents, consumables for sample preparation and characterization, such as reagents for sintering powder beds, refractory plates for high-temperature furnaces and other furnace consumables, special gases for the operation of equipment, containers, masks, protective goggles and gloves, etc.; and accessories (thermocouples, sensors, alumina or graphite tubes, vacuum circuit accessories, vacuum pump oil, etc.).

Also included are spatulas, sample storage containers, masks, stirrers, sieves, desiccators, crucibles, filters, disposable pipettes, protective eyewear, specific glassware, stirring plates, etc.

Consumables will also be required for sample preparation and characterization, such as sandpaper (grinding), polishing cloths/discs, diamond polishing pastes, cutting discs (diamond), holders for scanning electron microscopy, pattern for the X-ray diffractometer, carbon glues, diamond tips for mechanical tests, electrodes (reference and counter electrodes), AFM and SKPFM tips, material for mounting working electrodes and for building test cells, among others.

Gastos gerais	3 776,02 €	7 054,90 €	2 925,98 €	0,00 €	**13 756,90 €**
Total	**18 880,09 €**	**35 274,50 €**	**14 629,90 €**	**0,00 €**	**68 784,49 €**

Durit - Metalurgia Portuguesa do Tungsténio, Lda

Rubrica	2023	2024	2025	2026	Total
Recursos Humanos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Missões	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Instrumentos e equipamento científico e técnico	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Subcontratos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Registo de patentes	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstração, Promoção e Divulgação	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Adaptação de edíficios e instalações	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**

Rubrica	2023	2024	2025	2026	Total
Aquisição de bens e serviços	9 000,00 €	0,00 €	0,00 €	0,00 €	**9 000,00 €**
Justificação do financiamento solicitado WC powders and Binder materials (Co, Ni, Cr3C2 and Mo2C): 3000 € Laboratory consumables: 5000 € Sintering Consumables (thermocouples, graphite, etc): 10000 € Total: 18000 €					
Gastos gerais	2 250,00 €	0,00 €	0,00 €	0,00 €	**2 250,00 €**
Total	**11 250,00 €**	**0,00 €**	**0,00 €**	**0,00 €**	**11 250,00 €**

Durit - Metalurgia Portuguesa do Tungsténio, Lda AUTO FINANCIAMENTO

Rubrica	2023	2024	2025	2026	Total
Recursos Humanos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Missões	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Instrumentos e equipamento científico e técnico	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Subcontratos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Registo de patentes	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstração, Promoção e Divulgação	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Adaptação de edíficios e instalações	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Aquisição de bens e serviços	9 000,00 €	0,00 €	0,00 €	0,00 €	**9 000,00 €**
Gastos gerais	2 250,00 €	0,00 €	0,00 €	0,00 €	**2 250,00 €**
Total	**11 250,00 €**	**0,00 €**	**0,00 €**	**0,00 €**	**11 250,00 €**

Orçamento global

Rubrica	2023	2024	2025	2026	Total
Recursos Humanos	15 523,04 €	34 581,37 €	19 305,80 €	0,00 €	**69 410,21 €**
Missões	750,60 €	1 100,80 €	1 000,80 €	0,00 €	**2 852,20 €**
Instrumentos e equipamento científico e técnico	6 504,07 €	0,00 €	0,00 €	0,00 €	**6 504,07 €**
Subcontratos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Registo de patentes	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Demonstração, Promoção e Divulgação	8 025,87 €	12 001,14 €	10 850,54 €	0,00 €	**30 877,55 €**
Adaptação de edíficios e instalações	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Aquisição de bens e serviços	23 750,00 €	9 920,00 €	4 500,00 €	0,00 €	**38 170,00 €**
Gastos gerais	13 638,40 €	14 400,83 €	8 914,28 €	0,00 €	**36 953,51 €**
Total	**68 191,98 €**	**72 004,14 €**	**44 571,42 €**	**0,00 €**	**184 767,54 €**

Plano de financiamento

Rubrica	2023	2024	2025	2026	Total
Financiamento FCT	68 191,98 €	72 004,14 €	44 571,42 €	0,00 €	**184 767,54 €**
Autofinanciamento	11 250,00 €	0,00 €	0,00 €	0,00 €	**11 250,00 €**
Outros financiamentos públicos	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Outros fundos privados	0,00 €	0,00 €	0,00 €	0,00 €	**0,00 €**
Total	**79 441,98 €**	**72 004,14 €**	**44 571,42 €**	**0,00 €**	**196 017,54 €**

Declaração de compromisso

Investigador responsável

Eu, investigador responsável da presente candidatura, declaro:

1- Ter conhecimento de todos os dados e informações constantes da presente candidatura e que me responsabilizo pelo seu conteúdo e veracidade.

2- Ter conhecimento das disposições expressas no Regulamento nº 999/2016, de 31 de outubro, que estabelece as condições de acesso e as regras de apoio a projetos financiados exclusivamente por fundos nacionais através da Fundação para a Ciência e a Tecnologia, I.P. e do Aviso de Apresentação de Candidaturas do Concurso.

3- Não me encontrar em situação de incumprimento injustificado dos requisitos regulamentares no que respeita à apresentação de relatórios de execução científica de projetos concluídos em que também tenha desempenhado o papel de Investigador Responsável.

4- Comprometer-me a assumir a liderança do projeto e responsabilidades decorrentes da sua boa execução.

5- Assegurar o acesso aberto a publicações cientificas (peer-reviewed) resultantes da investigação financiada no âmbito deste Aviso para a Apresentação de Candidaturas, de acordo com as Políticas de Acesso Aberto da Fundação para a Ciência e a Tecnologia, I.P..

6- Caso tenha identificado em candidatura ou venham a ser futuramente identificadas questões de ética relacionadas com a execução do projeto, comprometo-me a:

a) diligenciar junto das instituições beneficiárias no projeto que, durante o período de execução do projeto, terão as permissões necessárias para executar projeto;

b) recolher toda a documentação necessária e a disponibilizá-la à FCT;

c) cumprir e a fazer cumprir pela equipa de investigação do projeto, toda a legislação nacional e comunitária aplicável neste domínio a este projeto de investigação.

☑ Tomei conhecimento e concordo com os termos enunciados na declaração de compromisso

Instituição Proponente

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